Identifying Concrete Plant Mixing Procedures for Electrically Conductive Concrete for the Iowa City Bus Stop Enhancement Project

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  - Bob Younie
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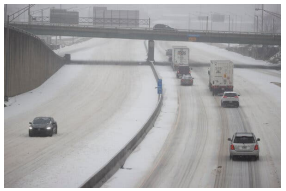
Introduction: Snow Events

(Photo: The New York Times- February 3, 2022)



(Photo: The New York Times- February 15, 2022)

(Photo: The New York Times- February 15, 2022)

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Introduction: Impacts on Transportation

(https://www.fhwa.dot.gov/innovation/everydaycounts/edc_4/roadweather.cfm)

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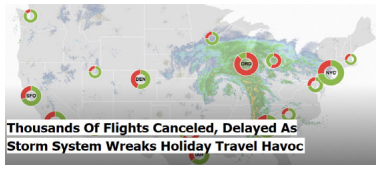
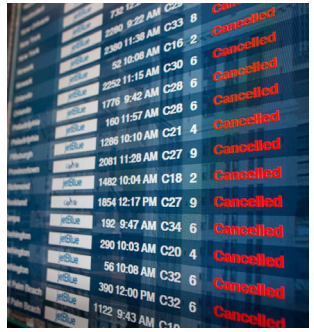
Introduction: Impacts on Transportation (Cont'd)

Total Cost of Delay in the U.S. (dollars, billion)

	2016	2017	2018	2019
Airlines	5.6	6.4	7.7	8.3
Passengers	13.3	14.8	16.4	18.1
Lost Demand	1.8	2.0	2.2	2.4
Indirect	3.0	3.4	3.9	4.2
Total	**23.7**	**26.6**	**30.2**	**33.0**





https://www.faa.gov/data_research/aviation_data_statistics/media/cost_delay_estimates.pdf

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Introduction: Snow Removal Traditional Method

(Photo: Wtopnews- January 21, 2016)

(Photo: Greenwise- February 15, 2017)

(Photo: Popular Science- February 5, 2019)

(Photo: Greenwise- February 15, 2017)

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Introduction: Drawbacks of Traditional Method

Infrastructure deterioration

Environmental pollution

Damage to pavement

(Shi 2011)

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Introduction: Innovative Technologies

- The transportation authorities continuously seek innovative and smart snow removal technology to combat their annual snow removal problem
  - Hydronically-heated pavement systems (HPS)
  - Resistive cable HPS
  - Phase-change-material integrated pavement systems
  - Superhydrophobic coating techniques
  - **Electrically-conductive concrete (ECON) HPS**

Reference: (Rahman et al., 2022)

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Introduction: Electrically Conductive Concrete (ECON)

- ECON, by virtue of its lower electrical resistivity compared to that of conventional Portland cement concrete (PCC), behaves like a resistive heating element
- Basic components of ECON
  - Portland cement
  - Aggregate (rock, sand, or gravel)
  - Water
  - Carbon fibers as conductive materials
  - Other components (if applicable): admixtures, supplementary cementing materials (SCMs), and so on

Electrically Conductive Concrete (ECON) → HEAT

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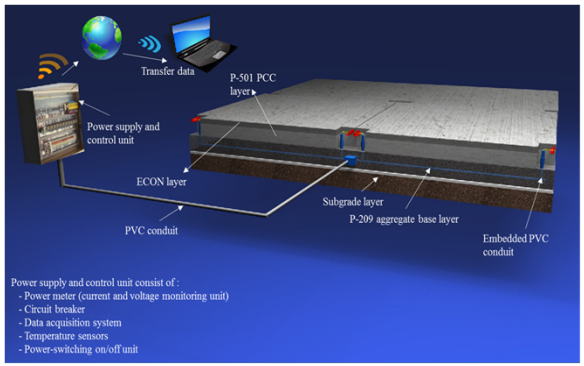
Introduction: ECON HPS



Reference: (Abdualla et al., 2018)

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Introduction: Field Implementations

Photo: DSM International Airport (Nahvi et al., 2018)

Photo: Iowa DOT Headquarter in Ames (Malakooti et al., 2020)

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Introduction: Problem Statement

- There have been discrepancies in ECON electrical resistivity between full-scale field construction and laboratory samples
  - The DSM International Airport ECON has an electrical resistivity eight times higher than the ECON produced in the laboratory[a]
  - The Iowa DOT ECON HPS encountered the same problem[b]

Reference: [a](Abdualla et al., 2018) [b](Malakooti et al., 2020)

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Introduction: Objective

- As part of a large-scale field implementation study on using ECON HPS for bus stop enhancement construction in Iowa City, this study aims to
  - determine mix proportion and mixing procedure of CF-based ECON suitable for ready-mix plant production

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Methodology: Mix Proportion

Item	Mix-1	Mix-2	Mix-3	Mix-4	Mix-5
cement, Kg (lb)	408 (899)	408 (899)	408 (899)	408 (899)	408 (899)
coarse aggregate, Kg (lb)	584 (1,287)	584 (1,287)	582 (1,284)	582 (1,284)	582 (1,284)
fine aggregate, Kg (lb)	475 (1,047)	475 (1,047)	474 (1,044)	474 (1,044)	474 (1,044)
water, Kg (lb)	171 (378)	171 (378)	171 (378)	171 (378)	171 (378)
w/cm	0.42	0.42	0.42	0.42	0.42
CF, Kg (lb)	17 (38)	17 (38)	19 (42)	19 (42)	19 (42)
AIRALON 7000, ml/m^3 (oz/yd^3)	193 (5)	193 (5)	174 (4.5)	213 (5.5)	155 (4)
ZYLA 630, ml/m^3 (oz/yd^3)	1,740 (45)	1,740 (45)	-	2,437 (63)	-
OptiFlo MR, ml/m^3 (oz/yd^3)	-	-	-	-	1,912 (49)
MIRA 62, ml/m^3 (oz/yd^3)	-	870 (22.5)	1,044 (27)	-	-

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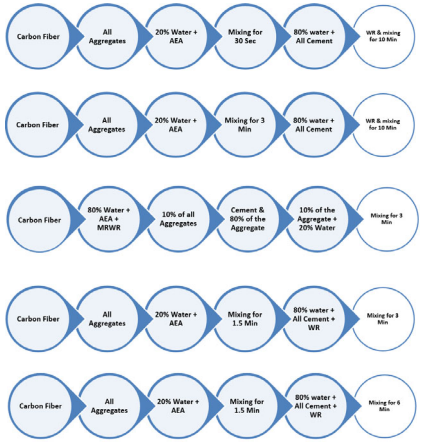
Methodology: Mix Procedures



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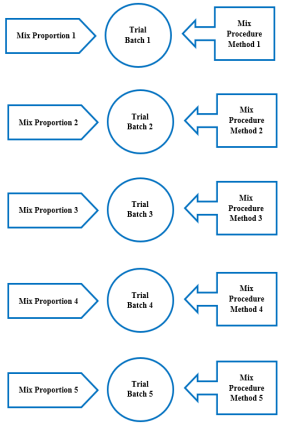
Methodology: Trial Batches



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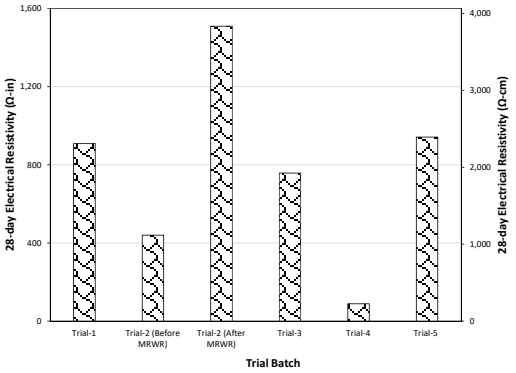
Results: 28-Day Electrical Resistivity



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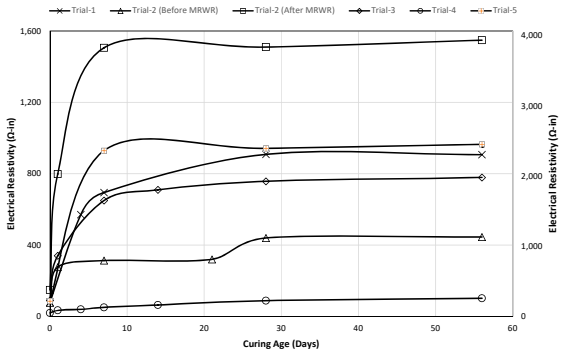
Results: Electrical Resistivity Vs Curing Time



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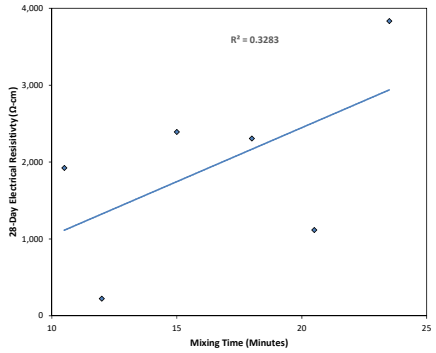
Results: 28- Day Electrical Resistivity Vs Mixing Time



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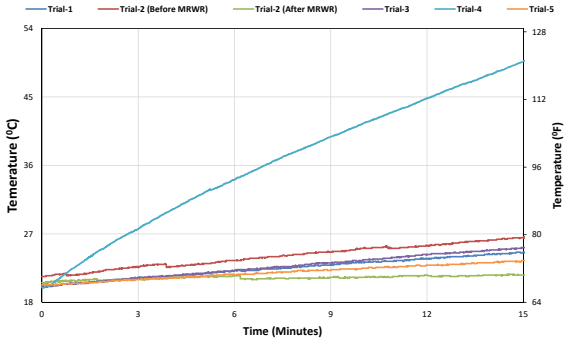
Results: Heating Performance



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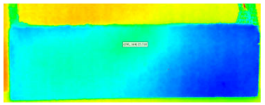
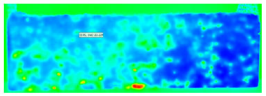
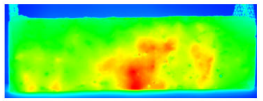
Results: Heating Performance (Trial Batch 4)



At the beginning



Immediately after applying voltage



After 15 minutes of voltage application

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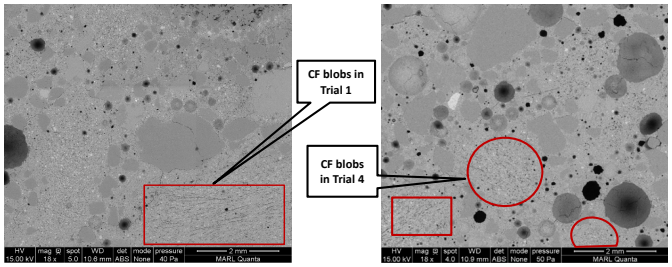
Results: Microstructure Evaluation



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Conclusions

- CF begins to degrade with an increase in mixing time.
- Mixture procedure method 4 using mixture proportion-5 produced ECON with the lowest electrical resistivity and highest heating rate.
- Estimating the 28-day electrical resistivity of ECON samples is possible after at least three days of curing; before that, electrical resistivity remains unstable and increases rapidly.

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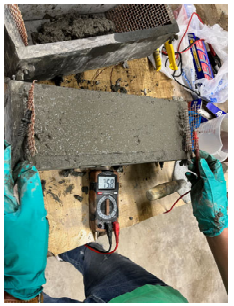
Thank You!
Questions & Comments?





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